5

# A History of Economic Research on Soil Conservation Incentives

*Steven Wallander, Daniel Hellerstein, and Maria Bowman*

**Soil conservation is a physical and technological problem, as well as economic, and it is essential that the interrelationships between these two aspects be clearly seen. The physical specialist needs to understand the economic implications of physical changes just as the economist needs to understand the physical factors which underlie the problem.**

**— Arthur C. Bunce, 1942, *The Economics of Soil Conservation***

Do farmers undertake "enough" soil conservation efforts? If not, why? The tools of economics are designed to help policymakers and conservation planners answer both of those questions. With these tools, economists define and measure the private and public benefits and costs that influence choices of soil conservation activities. In this chapter, we review the history of these tools. Based on scientific advances in our knowledge of soil processes, hydrology, water chemistry, and other areas, economists have improved our understanding of how the incentives to undertake immediate soil conservation actions are related to current costs, future on-field benefits, and future off-field benefits. A variety of policy options are available if these incentives are not properly aligned, but every policy option faces its own set of complex incentives.

Soil conservation economics cannot be summarized by a single value for soil. Like soil itself, the value of soil conservation practices are highly variable.

**Steven Wallander** and **Daniel Hellerstein** are economists with the USDA Economic Research Service, Washington, DC. **Maria Bowman** is lead scientist for the Soil Health Partnership, National Corn Growers Association, Chesterfield, Missouri.

Spatial and temporal variation are tremendously important, especially for economic analysis of conservation policy. Other variation in the value of soil, particularly around the multiple benefits that come from conserving soil, is often the primary focus of soil conservation economists.

## The Early Foundations: Environmental Externalities

Most of the tools that economists currently use—dynamic optimization models, partial equilibrium models, econometrics, game theory, risk aversion models, and market and nonmarket valuation methods—were developed within the past 50 to 75 years. The idea of environmental externalities, which is the framework for applying these economic tools to analysis of soil conservation, has much earlier origins.

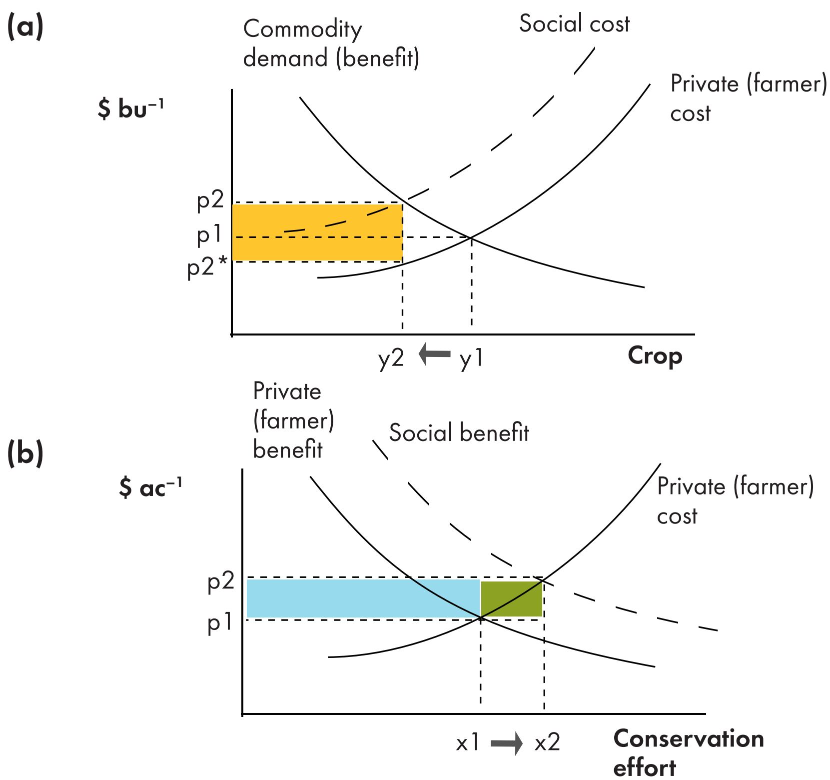
Concern over the potentially detrimental impact of agricultural production on neighboring individuals was noted as far back as the late 1700s by the Marquis de Condorcet, as detailed in Sandmo (2015). Condorcet argued that a sufficiently negative impact could justify restrictions on where agricultural production can occur, making perhaps the earliest proposal for rural zoning.

By the late 1800s, economists had developed the core mathematical system of demand and supply curves. Modeling market incentives in this way allowed economists to explore the implications of changes in marginal benefits (demand) and marginal costs (supply). In this framework, the observed allocation of any good (e.g., cars, electricity, corn, or doctors) is an equilibrium outcome captured in both quantity and price for that good. Changes in many other factors (e.g., policies, income, or other prices) can shift either the demand or the supply curve leading to a new equilibrium. Fitting the "good" of soil conservation into this framework required a number of additional developments in the field.

Pigou (1920) incorporated the issues raised by Condorcet and others into this supply and demand framework by conceptualizing pollution as an "externality." In Pigou's treatment, the negative impacts of pollution are costs imposed on the damaged parties and, most importantly, are not reflected in the production decisions of the polluting firms. In other words, firms make decisions on how much output to produce based on their costs, but those costs do not include disposing of or abating their pollution. Pigou's model is an enormously important tool for economists because it provides the theory on which to identify the equilibrium associated with a baseline in which some costs, such as the off-site impacts of conventional agricultural production, are ignored by markets, and also to identify the optimum allocation of resources that would occur if policy could fully "internalize" all of the costs and benefits of pollution abatement (figure 1a). The important feature of externalities is

**Figure 1**

**Two models of soil conservation as an externality: (a) Pigou's model where negative impacts of crop production are an external cost in crop production; and (b) an impure public good model where the social benefits of soil conservation get added to the private farmer benefits.**




**Notes: Under (a), Pigou's model of pollution as an external cost within the market for a production output, internalizing the social costs of crop production will lead to a decrease from the initial equilibrium (y1) to the social optimum (y2). This change can occur with a Pigouvian tax on crop production of p2 – p2*, which increases the price that consumers pay from p1 to p2 and decreases the price that producers receive from p1 to p2*. The tax generates revenue of y2(p2 – p2*) shown as the yellow box. Under (b), an impure public good model of soil conservation effort, the private benefits and costs to farmers lead to an equilibrium amount of conservation effort of x1. Incorporating the public benefits through a subsidy of p2 – p1 on all conservation efforts increases the amount of total effort to x2. The subsidy costs x2(p2 – p1). The portion shown as the green box is the revenue that goes to the "additional" increase conservation effort. The portion of that cost shown as the blue box is payments to conservation effort that would have been undertaken without the subsidy based only on the private benefits, which is called "nonadditional" spending.**

that they represent a form of market failure because the costs associated with pollution will remain external to market decisions without some sort of policy response. Essentially, the model says that some activity, in this example crop production, causes a certain amount external damages, and taking those into account would lead to less of that activity. Although rarely implemented as an actual policy, the use of a tax equal to the marginal value of external damages would be effective at reducing the total amount of the polluting activity. While policy tools other than taxes can also be used, this modeling framework only provides specific policy insights if external costs can be appropriately modeled through use of damage functions. For example, a damage function for coal-fired electricity generation would map the megawatts of electricity generated from coal-fired plants into a dollar value of damages.

Pigou's framework eventually became a cornerstone of environmental economics, but it took a long time. Initially, within the subtopic of the economics of soil conservation, many economists remained skeptical that there could be significant externalities associated with poor soil management practices, arguing that most of the benefits of soil conservation accrued on the farm (Ciriacy-Wantrup 1947). The focus on the private on-farm benefits of soil conservation did ultimately contribute to increased efforts of soil conservation as agronomists and farmers learned more about the link between their management decisions and outcomes such as long-run productivity. However, alongside this on-farm focus, the public off-farm benefits of soil conservation also began to play a major role in both policy and in the study of soil conservation economics.

Bunce (1942) directly attempted to incorporate Pigou into soil conservation economics, but he argued that the main externality involved was increased flooding due to more rapid runoff and higher downstream peak flows from more poorly managed soils. Most of Bunce's analysis was focused on specifying the drivers of erosion, which he viewed as representing a permanent loss of productive capacity, and of depletion of soil nutrients, which he viewed as replaceable with other inputs (such as fertilizer). On the issue of erosion, Bunce focused on the role of commodity markets in driving the rapid expansion of cropland in the 1910s and 1930s. For both erosion and nutrient depletion, he outlined the factors that can influence the on-farm benefits of investing in conservation efforts: interest rates, cash crop rotation, specific soil characteristics, land ownership and tenure relationship, and even education levels. Much of the research at this point, though, was theoretical and somewhat heuristic, lacking detailed mathematical structure. In part, this reflected the fact that the relationships between soil characteristics, crop yields, and nutrient requirements were not precise enough to support detailed economic models.

The early attention to on-farm benefits was consistent with the belief that a lack of information and limited sources for education were the primary reasons for insufficient soil conservation efforts. The creation of the Agricultural Extension Service in the 1914 Smith-Lever Act was an effort to address this issue. A greater focus on the difference between the private and public benefits of soil conservation would come in the 1970s and 1980s. The full implications of these different benefits, particularly in the context of voluntary conservation programs, received much greater attention in the 1990s and 2000s (Segerson 2013).

## Recent History: Targeting Conservation Using Public Net Benefits

Modeling environmental externalities in soil conservation was initially difficult. Not surprisingly, the details of how environmental systems convey, filter, and concentrate pollution have significant implications for the economics. Pigou's model simply asserts that certain production activities—such as farming—impose external costs. Future research would have to specify the mechanism through which these costs are imposed and figure out how to measure these costs.

As the physical sciences revealed the mechanisms behind different types of pollution—the nutrient cycle, water chemistry, hydrology, hydrogeomorphology, the carbon cycle, and climatology—economics followed along. Economists were concerned that simple descriptions of environmental externalities, such as Garrett Hardin's idea of the "commons," were not adequate descriptions of all types of pollution (Hardin 1968). In response, during the 1960s and 1970s economists developed a framework for characterizing different types of "goods."

The two most commonly studied goods within this framework are private goods and public goods. Private goods, such as agricultural commodities, can only be used by one person at a time. They are both "excludable" and "rival." Public goods, such as clean air and water, can be enjoyed by anyone and everyone simultaneously.

The challenge of soil conservation, from an economic perspective, is that it has elements of both private and public goods. The on-field benefits, such as productivity, are generally private goods that benefit a single user, the farmer. The off-field benefits, such as abatement of pollution in runoff, are generally public goods that benefit many users, such as everyone downstream in the watershed (Clark 1985). To address situations where a private good, such as the benefit of soil productivity to a farmer, is supplied jointly with a public good, such as the benefit of reduced nutrient losses to streams and lakes, economists define the joint good as an impure public good, which allows for better empirical models of the concepts raised by Bunce and Ciriacy-Wantrup.

To reconfigure Pigou's model based on the idea of impure public goods, we define the equilibrium in terms of soil conservation activity (figure 1b). Based on the private benefits and costs, a certain amount of soil conservation (x1) will occur at the baseline per acre cost (p1). Reaching the optimum soil conservation based on both the private and public benefits and the private costs requires a subsidy equal to the marginal public benefits of soil conservation, which increases the total amount of conservation provided (x2). While this model resembles current conservation programs, which use government payments to change the marginal incentives for soil conservation, it also requires detailed knowledge about the public and private benefits of soil conservation. Importantly, public benefits are added vertically to the private benefits due to the nonexcludable nature of public goods. The same is true when looking at public costs in the Pigou version of the model.

Estimating the value of soil conservation is complicated by two issues: the complex biophysical links between conservation practices and productivity, and the time-lags involved in seeing the benefits of good soil management or the costs of bad soil management. A common approach by economists is to use "revealed preference" valuation techniques that use observed data on decisions made by people, such as landowners or farmers or ranchers, to estimate their perceived net benefits of alternative choices (Hansen and Ribaudo 2008). Adopting these estimation tools assumes that farmers understand the links between soil health and farm profits in a way that gets captured in land markets.

For example, hedonic models statistically analyze land prices or cropland rental rates to estimate the value of a marginal ("small") improvement in some parameter of soil quality (Palmquist and Danielson 1989). While these studies support the Ciracy-Wintraup idea that farmers understand and incorporate the value of soil conservation into their decisions, a positive hedonic price on soil quality does not rule out the existence of potentially significant externalities. In an alternative approach, some studies simulate the returns to soil conservation using agronomic models of predicted changes in soil characteristics under alternative management approaches to a model of expected net revenue (Colacicco et al. 1989). More recent versions of both structural and revealed preference models include models that estimate the value of risk management benefits from healthier soils (Williams et al. 2016).

Public goods are more difficult to value, but many involve water quality (Holmes 1988). These models require hydrological and chemical models that link on-field conservation efforts to some sort of public good. The economic challenge is putting a dollar value on the marginal improvements in the public good that result from a change in conservation practices. Revealed preference approaches are also common here, although in this case it is the public, not farmers, whose market decisions reveal the extent to which they value water quality or air quality or some other good. For example, by examining where people choose to go for vacation or recreation trips, travel cost models can estimate the impact of water quality on recreational benefits. Hedonic analysis can estimate the impact of water quality on property values. When revealed preference approaches cannot be used, economists often turn to other methods. These include stated preference approaches, which use a survey that is structured to elicit values based on hypothetical choices. Programming tools, another approach, mathematically simulate the underlying choice problem and often include damage function analysis of outcomes such as the impact on water storage and treatment. An additional approach is averting cost analysis, which works for many public health–related benefits (Hansen and Ribaudo 2008). More recent efforts also examine the benefits of soil carbon sequestration (Bradford et al. 2019).

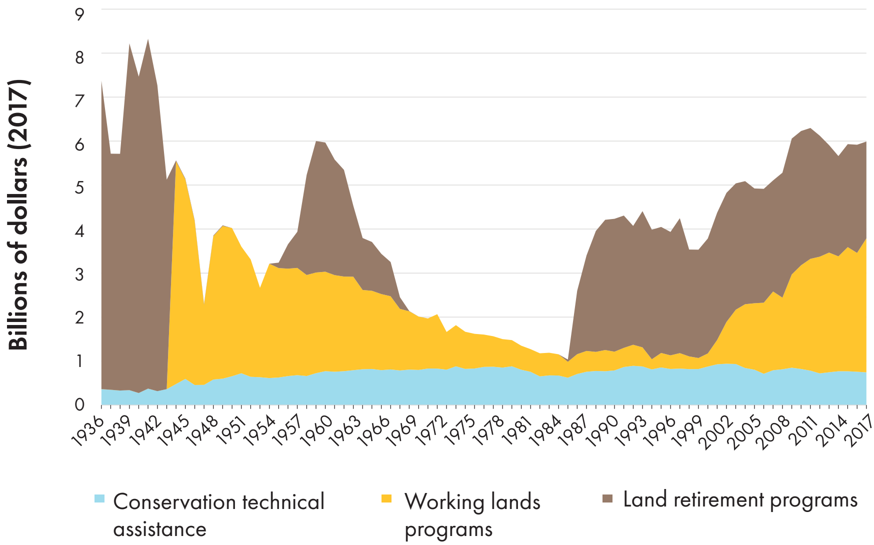
Beyond valuation of the public and private benefits, economic tools involve models of how different policies adjust the incentives for soil conservation. Financial incentives through subsidies for abatement activities, typically through conservation program contract payments and cost share, are common. In contrast, the regulatory approach suggested by Condorcet and output taxes suggested by Pigou are rarely used. Markets for environmental services, such as water quality trading efforts, are a combination of a regulatory approach and the financial incentives approach. The financial incentives in this setting are payments to unregulated individuals, often farmers, to provide an environmental service such as reduced nutrient runoff, which then reduces the regulatory requirement placed on another entity, often water treatment plants or industrial polluters. While various pilots for conservation trading platforms have developed, they are rarely sustained at large scale (Ribaudo et al. 2010).

For any of these policy tools, spatial variation in both the public and private benefits of soil conservation is a critical driver of actual economic outcomes. For at least the past 50 years, economists have studied the implications of different targeting approaches. Targeted policies direct either financial incentives or regulation toward those fields and farmers that will have the highest net public benefits. Early calls for targeting based on soil erosion involved the Conservation Reserve Program (CRP) (Ogg et al. 1982). Importantly, targeting cannot occur without underlying biophysical and economic data. The development of the Natural Resource Inventory provided the basis for understanding regional differences in erosion (Schnepf and Flanagan 2016). The development of parcel-specific measures of soil erodibility based on the

Soil Survey Geographic Database data allowed for targeting of both CRP and conservation compliance provisions (Claassen 2004), both of which targeted highly erodible land. Prior land retirement programs were similar in scale, in inflation-adjusted spending to CRP (figure 2). While the farm economic crisis

**Figure 2**

**Changes over time in three main types of US Department of Agriculture financial incentives for soil conservation: conservation technical assistance; land retirement of highly erodible land (such as the Conservation Reserve Program); and working lands cost share (such as the Environmental Quality Incentives Program and the Conservation Stewardship Program).**




**Updated from Pavelis et al. (2011) using data from US Department of Agriculture Office of Budget and Program Analysis and inflation adjustment to 2017 dollars with nondefense expenditures and gross investment index from the Bureau of Economic Analysis.**

of the 1980s provided a similar motivation for land retirement to earlier crises, particularly the Dust Bowl and Great Depression, targeting made CRP fundamentally different from the earlier programs (Hellerstein 2017). By focusing on higher benefit land, CRP combined a desire for farm support with an effort to correct an environmental externality, the underprovision of what is now referred to commonly as environmental services. However, the Environmental Benefits Index and other targeting mechanisms often are unclear on the distinction between private and public benefits (McConnell 1983). An important aspect of any targeting effort is that they typically impose transaction costs on both program managers and potential participants (Claassen et al. 2008).

Targeting has major implications for the behavior of participants in voluntary conservation programs, whether the land retirement programs described above or for working lands programs, which encourage conservation practice adoption on land that is in active agricultural production. Economists are particularly focused on two issues: whether some portion of program payments is going to participants who would have adopted the conservation practices anyway; and whether any changes in conservation practice adoption leads to compensating behavior (Segerson 2013). The possibility of payments going to conservation practices that would have occurred without payment, which economists call "nonadditionality," is evident in the model shown in figure 1b. For example, working land programs have provided considerable financial assistance for the adoption of no-till production; however, much of the increase in no-till adoption occurred prior to the large increase in working lands programs in the 2002 Farm Act. Other key incentives for no-till adoption include the conservation compliance provisions in the 1986 Farm Act (Claassen 2004) and the adoption of herbicide-tolerant crops, which are much more compatible with a no-till system (Fernandez-Cornejo et al. 2012) (figure 3).

## Future Directions: Program Design, Experiments, and Soil Health

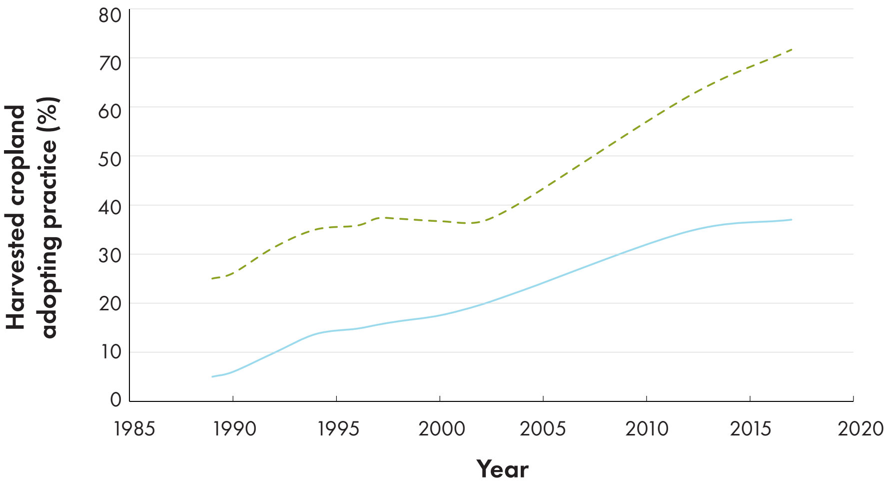
From the early 1940s until well into the 1990s, economists were focused on broad policy questions built largely on theoretical models. Economists tended to ask questions like, How do subsidies for pollution abatement compare to a tax on pollution? Increasingly, economists are focusing on finer details, the sort of policy questions that occupy many program design discussions. One of the seminal calls for this is for economists to work more as "plumbers" in the policy research process, focusing on how to implement a policy rather than the policy itself (Duflo 2017). Within soil conservation, this trend is likely to progress by leading to research that focuses on detailed aspects of conservation auction design (Whitten et al. 2017) and conservation contract structure.

Another major shift in economics is the move toward experimental methods that can answer targeted policy effectiveness questions (Ferraro and Hanauer 2014). When implemented within actual programs, these "field" experiments reveal how seemingly simple decisions, such as sending enrollment reminder letters, can have significant impacts on program outcomes (Wallander et al. 2017).

A third important trend for the future of the soil conservation economics is how economic models will have to adjust to the idea of soil health. In contrast to soil conservation, which largely focuses on the impact of conservation

**Figure 3**

**Trends and major change in incentives for no-till adoption (solid blue line) and conservation adoption (dashed green line) inclusive of no-till based on Economic Research Service Agricultural Resources and Environmental Indicators data (1985), Conservation Technology Information Center data (1990 to 2004), and USDA Census of Agriculture (2012 and 2017).**




**1985:** Farm Act introduces conservation compliance rules

**1996:** Farm Act creates Environmental Quality Incentives Program (EQIP)

**2002 to 2004:** Farm Act quadruples funding for EQIP

**2007:** Herbicide tolerant seed adoption hits 50% for corn

behavior on reducing negative outcomes, the shift toward soil health in policy and science in the United States emphasizes the positive impacts of managing for soil health on soil structure and function, productivity, and environmental outcomes. In part, the growing interest in soil health, which both reflects advancing science and a reframing of traditional issues, is an example of the importance of framing effects, the idea that the language used to talk about an issue can influence behavior (Stevens 2018). Another challenge is the growing recognition that soil conservation practices result in multiple private and public goods. The interaction between these is complex and can lead to competing policy recommendations (Bowman 2018; Bradford et al. 2019).

## Conclusion

Prior to the 1940s, the most important tools for soil conservation economics were theoretical models that recognized the importance of environmental externalities. This development mirrored the early developments in soil science. Over the past 75 years, economics tools have again followed the soil science in recognizing the complex and dynamic nature of soil conservation. On the economics side, this has involved developing tools that capture both on-farm, private benefits and costs, and off-farm, public benefits of soil conservation. Spatial variation in these costs and benefits means that targeting, based on biophysical and economic data, is a critical focus point for economic tools. The future of soil conservation economics is largely centered around the complexity of the policy tools required to move toward better soil conservation outcomes.


### Acknowledgement

The authors would like to thank Roger Claassen (USDA Natural Resources Conservation Service) for feedback on this article and assistance with acquiring the necessary data.


### Disclaimer

The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or US Government determination or policy. This research was supported by the USDA Economic Research Service.

### Resources to Learn More

- USDA Economic Research Service, Environmental Quality. https://www.ers.usda.gov/topics/natural-resources-environment/environmental-quality/
- USDA Economic Research Service Report on Agri-Environmental Indicators. https://www.ers.usda.gov/publications/pub-details/?pubid=93025
- USDA Natural Resources Conservation Service Resources Conservation Act Reports. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/rca/
- Soil Health Partnership. https://www.soilhealthpartnership.org/
- Soil Health Institute. https://soilhealthinstitute.org/
- Center for Behavioral and Experimental Agri-environmental Research (CBEAR). http://centerbear.org/

### References


Bowman, M. 2018. The economics of soil health. *In* Managing Soil Health for Sustainable Agriculture (Vol. 1), ed. D. Reicosky. Cambridge, UK: Burleigh Dodds Science Publishing.

Bradford, M.A., C.J. Carey, L. Atwood, D. Bossio, E.P. Fenichel, S. Gennet, and S.A. Wood. 2019. Soil carbon science for policy and practice. Nature Sustainability 2(12):1070-1072, doi:10.1038/s41893-019-0431-y.

Bunce, A.C. 1942. The Economics of Soil Conservation. Ames, IA: Iowa State College Press.

Ciriacy-Wantrup, S.V. 1947. Capital returns from soil-conservation practices. Journal of Farm Economics 29(4):1181-1196, doi:10.2307/1232747.

Claassen, R. 2004. Have conservation compliance incentives reduced soil erosion? Amber Waves, June 1. Washington, DC: USDA Economic Research Service.

Claassen, R., A. Cattaneo, and R. Johansson. 2008. Cost-effective design of agri-environmental payment programs: U.S. experience in theory and practice. Ecological Economics 65:737-752.

Clark, E. 1985. The off-site costs of soil erosion. Journal of Soil and Water Conservation 40(1):19-22.

Colacicco, D., T. Osborn, and K. Alt. 1989. Economic damage from soil erosion. Journal of Soil and Water Conservation 44(1):35-39.

Duflo, E. 2017. Richard T. Ely Lecture: The economist as plumber. American Economic Review 107(5):1-26, doi:10.1257/aer.p20171153.

Fernandez-Cornejo, J., C. Hallahan, R. Nehring, S. Wechsler, and A. Grube. 2012. Conservation tillage, herbicide use, and genetically engineered crops in the United States: The case of soybeans. AgBioForum 15(3):231-241.

Ferraro, P.J., and M.M. Hanauer. 2014. Advances in measuring the environmental and social impacts of environmental programs. Annual Review of Environment and Resources 39(1):495-517, doi:10.1146/annurev-environ-101813-013230.

Hansen, L., and M. Ribaudo. 2008. Economic measures of soil conservation benefits: Regional values for policy assessment. USDA Technical Bulletin (1922). Washington, DC: USDA.

Hardin, G. 1968. The tragedy of the commons. Science 162(3859):1243-1248.

Hellerstein, D.M. 2017. The US Conservation Reserve Program: The evolution of an enrollment mechanism. Land Use Policy 63:601-610.

Holmes, T.P. 1988. The offsite impact of soil erosion on the water treatment industry. Land Economics 64(4):356-366, doi:10.2307/3146308.

McConnell, K.E. 1983. An economic model of soil conservation. American Journal of Agricultural Economics 65(1):83-89.

Ogg, C.W., J.D. Johnson, and K.C. Clayton. 1982. A policy option for targeting soil conservation expenditures. Journal of Soil and Water Conservation 37(2):68-72.

Palmquist, R.B., and L.E. Danielson. 1989. A hedonic study of the effects of erosion control and drainage on farmland values. American Journal of Agricultural Economics 71(1):55-62, doi:10.2307/1241774.

Pigou, A.C. 1920. The Economics of Welfare. London: Macmillan.

Ribaudo, M., C. Greene, L. Hansen, and D. Hellerstein. 2010. Ecosystem services from agriculture: Steps for expanding markets. Ecological Economics 69(11):2085-2092.

Sandmo, A. 2015. The early history of environmental economics. Review of Environmental Economics and Policy 9(1):43-63.

Schnepf, M., and P. Flanagan. 2016. A History of Natural Resource Inventories Conducted by the USDA's Soil Conservation Service and Natural Resources Conservation Service. Ankeny, IA: Soil and Water Conservation Society. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcseprd1212208.pdf.

Segerson, K. 2013. When is reliance on voluntary approaches in agriculture likely to be effective? Applied Economic Perspectives and Policy 35(4):565-592, doi:10.1093/aepp/ppt030.

Stevens, A.W. 2018. Review: The economics of soil health. Food Policy 80:1-9. https://doi.org/10.1016/j.foodpol.2018.08.005.

Wallander, S., P. Ferraro, and N. Higgins. 2017. Addressing participant inattention in federal programs: A field experiment with the conservation reserve program. American Journal of Agricultural Economics 99(4):914-931.

Whitten, S.M., T. Wünscher, and J.F. Shogren. 2017. Conservation tenders in developed and developing countries  status quo, challenges and prospects. Land Use Policy 63:552-560.

Williams, A., M.C. Hunter, M. Kammerer, D.A. Kane, N.R. Jordan, D.A. Mortensen, and A.S. Davis. 2016. Soil water holding capacity mitigates downside risk and volatility in US rainfed maize: Time to invest in soil organic matter? PloS one 11(8):e0160974. https://doi.org/10.1371/journal.pone.0160974.